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LANDSAT DATA CONTINUITY MISSION

OPERATIONAL LAND IMAGER SPECIAL CALIBRATION TEST REQUIREMENTS

November 2, 2006

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

CM FOREWORD

This document is a Landsat Data Continuity Mission (LDCM) Project Configuration Management (CM)-controlled document. Changes to th document require prior approval of the applicable Configuration Control Board (CCB) Chairperson or designee. Proposed changes shall be submitted to the LDCM CM Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

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Document Revision History

This document is controlled by the LDCM Project Management. Changes require approval of the LDCM Project Manager, LDCM OLI Manager, and the LDCM Mission Assurance Manager. Proposed changes shall be submitted to LDCM Systems Engineering Manager.

RELEASE	DATE	BY	DESCRIPTION
–			Initial Version

List of TBD's/TBC's/TBR's

This document contains information that is complete as possible. Items that are not yet defined are annotated with TBD (To Be Determined). Where final numerical values or data are not available, best estimates are given and annotated TBC (To Be Confirmed). If there is an inconsistency between two requirements then the best estimate is given and annotated with a TBR (To Be Resolved). The following table summarizes the TBD/TBC/TBR items in the document and supplements the revision history.

ITEM	REFERENCE	DESCRIPTION
		Data not supplied

Table of Contents

1 Introduction

1.1 Purpose

The LDCM program elements are dependent on the pre-flight and on-orbit commissioning phase characterization and calibration of the imaging sensor and related subsystems, and, in particular, on the data sets and written reports from those tests. It is through the preflight test reports that the required elements of the Image Assessment System will be identified. In addition, the algorithms and input parameters to process the image data will be developed using these preflight data sets.

The purposes of the pre-flight and commissioning phase test requirements are to:

- verify that the instrument's operation conforms to specifications;
- establish the instrument's as-built performance;
- test for abnormalities in the sensor's response;
- provide an at-launch estimate of the sensor's radiometric calibration;
- provide characterization data sets that are otherwise unobtainable in flight or on the ground (such as spectral band characteristics, PSF parameters, and solar diffuser reflectance); and
- determine the instrument's radiometric stability.

The LDCM contractor has the responsibility for providing an instrument(s) capable of providing well calibrated, well characterized and specification compliant data, to ensure Landsat data continuity. The Government has the responsibility for independently assuring that the delivered instrument will be specification compliant and sufficiently well calibrated and characterized to fulfill the Mission objectives. The following Special Calibration Test Requirements (SCTR's) are an essential component of that independent assurance program

1.2 Definitions

The observatory elements identified in Figure 1-1 and defined below are provided for clarification of terms used in the SCTR and are not intended to dictate a design implementation.

Refer to the LDCM Acronym List and Lexicon for more Definitions.

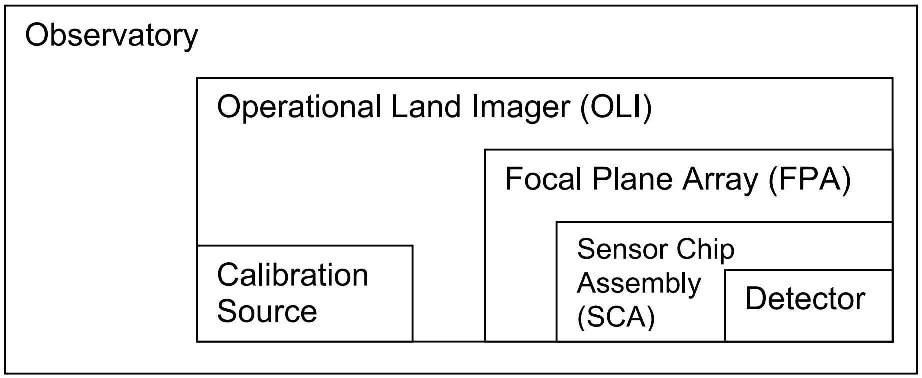

Figure 1-1 Relationship of Elements in the SCTR

Operational Land Imager (OLI) – The LDCM sensor payload designed to collect data for the LDCM reflective bands 1 through 9 (433-2300 nm).

Sensor - The integrated instrument comprising optics, spectral bandpass filters, sensing elements, electronics, calibration source(s), and associated mechanisms and structural elements.

Focal Plane Array (FPA) – The detectors and associated electronics assembled with the spectral bandpass filters. A focal plane array comprises one or more sensor chip assemblies illuminated by a common optical path, and the associated electronics.

Calibration Source – A component of the sensor that provides controlled and/or measured reference radiance input to the RBS sensing elements for purposes of calibration.

Simulated On-Orbit Operating Conditions – Temperature and pressure environmental conditions similar to those experienced on-orbit, i.e., thermal vacuum.

Vacuum – Atmospheric pressure of 10-5 torr or less as defined in the General Environmental Verification Standard (GEVS) For GSFC Flight Programs and Projects.

Operational Temperature Range – The range of temperatures over which an LDCM subsystem or component is designed to operate while meeting all specifications.

Determine – Use one or more measurements and associated analyses to estimate the value for a particular system parameter or performance characteristic

1.3 Scope

The following test requirements do not constitute a complete set of tests. The Contractor is responsible for verification and validation of all LDCM requirements. The tests described herein shall be included as part of the Contractor's overall validation program as required in the Calibration/Validation Plan CDRL (CV-1). The contractor shall report the results of these tests in accordance with the Calibration/Validation Test Report CDRL (CV-3). For selected tests, indicated by "(CV-9)" following the test description, the image data collected during these tests shall be provided to the government in accordance with CDRL CV-9.

2 General Test Requirements

2.1 Sampling methods and their statistical validity shall be described in the calibration/validation plan CDRL CV-1.

2.2 The sampling of the instrument and focal plane temperatures to be used for the characterizations shall be described in the calibration/validation plan (CV-1).

2.3 The Contractor shall calibrate radiance calibration sources to National Institute of Standards and Technology (NIST) standards for radiometric calibrations.

3 Pre-flight Test Requirements

3.1 Spectral Test Requirements

3.1.1 The Contractor shall measure the spectral transmission of the spectral bandpass filters per the parameters in table 3.1-1.

3.1.2 The Contractor shall measure the relative spectral radiance response of a sample of detectors per the parameters in table 3.1-1.

3.1.3 The Contractor shall measure the spectral transmission or reflectance of the optical elements of the instrument telescope per the parameters in table 3.1-1.

3.1.4 The Contractor shall measure the in-band relative spectral radiance response of the instrument per the parameters in Table 3.1-1 (note a. and b. sub-requirements).

3.1.5 The Contractor shall determine the out-of-band relative spectral radiance response of the instrument for each band via measurements conducted per the parameters in Table 3.1-1.

3.1.6 The Contractor shall characterize the stability of the spectral transmission of the spectral band bandpass filters between ambient pressure and vacuum conditions per the parameters in Table 3.1-1.

3.1.7 The Contractor shall measure the spectral transmission of the thermal vacuum chamber optical window per the parameters in Table 3.1-1.

Rationale: These spectral calibration tests are used to determine compliance with OLI spectral requirements (section 5.4 of OLI Requirements Document [OLIRD]). Also, these measurements are required in order to perform the radiometric calibration of the instrument and provide the user community the fundamental spectral characteristics of the data. The component level measurements

(3.1.1 – 3.1.3) will be used to predict the system level response and assure the final system will likely meet relative spectral response requirements; however, measuring the response on the assembled instrument in as close to operational conditions as possible is required for an adequate characterization (3.1.4). The spectral uniformity requirement, in particular, requires characterization of the variation in the system level responses (section 5.6.2.3 of OLIRD). It is difficult to obtain sufficient energy to measure the out-of-band response at the integrated instrument level, so measurements at the detector mated to filter assembly level are allowed for this characterization (3.1.5). Spectral bandpass filters have historically shown stability problems in the transition from ambient to vacuum conditions, apparently due to the outgassing of absorbed water. Current filter fabrication techniques have reduced this problem significantly; test 3.1.6 is intended to verify that the OLI filters do not have this problem and will likely meet the spectral stability requirement for OLI (section 5.4.5 of OLIRD). The spectral and radiometric characterizations of the integrated instrument will occur with the instrument in the Thermal Vacuum chamber and the calibration sources outside; a characterization of the spectral transmission of the optical window is thus required.

Table 3.1-1: Spectral Test Minimum Acceptable Requirements

Test	Assembly Level	Unit	Measurement Conditions	Samples	Wavelength Range	Wavelength Sampling and Wavelength Resolution (FWHM)	Precision	Other
3.1.1	Component	Filter	Operational angular and temperature conditions	5 per flight filter wafer	Across range of sensitivity (to 0.0001 of peak response) of detectors	In-band: 1 nm below 1 µm; 2 nm above 1 µm Out-of-band: 5 nm below 1 µm; 10 nm above 1 µm	0.001 (1 σ) in band; SNR >10 down to 0.0005 of peak trans.	
3.1.2	Component	Detector	Operational angular and temperature conditions	1% of detectors uniformly distributed across each flight SCA per band	Across range of sensitivity (to 0.0001 of peak response) of detectors	In-band: 1 nm below 1 µm; 2 nm above 1 µm Out-of-band: 10 nm below 1 µm; 20 nm above 1 µm	0.001 (1 σ) in band; SNR >10 down to 0.0005 of peak	
3.1.3	Component	Optical Surfaces / witness samples	Operational angular and temperature conditions	3 samples of each optical surface	Across range of sensitivity (to 0.0001 of peak response) of detectors	In-band: 1 nm below 1 µm; 2 nm above 1 µm Out-of-band: 10 nm below 1 µm; 20 nm above 1 µm	0.001 (1 σ) in band; SNR >10 down to 0.0005 of peak	
3.1.4.a	Integrated Instrument		Vacuum; operational focal plane temperature	Same detectors as in 3.1.2	Between 0.005 response points	1 nm below 1 µm; 2 nm above 1 µm	0.01 (1 σ) above 0.1 RSR; SNR >10 below 0.1 RSR	

3.1.4.b	Integrated Instrument		Vacuum; operational focal plane temperature	10% of detectors uniformly distributed across focal plane	Between 0.005 response points	2 nm below 1 μm; 4 nm above 1 μm	0.01 (1 σ) above 0.1 RSR; SNR >10 below 0.1 RSR	
3.1.5	Assembly or above	Mated Filter/ Detector Assembly Level or above	Operational angular and temperature conditions with adjacent bands illuminated	Same detectors as in 3.1.2	Across range of sensitivity (to 0.0001 of peak response) of detectors	10 nm below 1 μm; 20 nm above 1 μm	SNR >10 down to 0.0005 of peak response	Use 3.1.3 results to represent optics if no instrument level test
3.1.6	Component	Filter witness samples	Ambient conditions then in vacuum after 1, 3, 5 and 7 days of vacuum exposure	1 filter per band; 3 spots per filter	Across range of sensitivity (to 0.0001 of peak response) of detectors	In-band: 1 nm below 1 μm; 2 nm above 1 μm; Out-of band: 5 nm below 1 μm, 10 nm above 1 μm	0.001 (1 σ) in band; SNR of >10 down to 0.0005 of peak trans.	Repeat ambient measure-ments every 6 months until launch.
3.1.7	Test Equipment	T/V Chamber Optical Window	Ambient Conditions	5 spots	Across range of sensitivity (to 0.0001 of peak response) of any band's detectors	Within any band's in-band response: 1 nm below 1 μm; 2 nm above 1 μm; Out-of-band: 5 nm below 1 μm, 10 nm above 1 μm	0.001 (1 σ) in band; SNR of >10 down to 0.0005 of peak	

3.2 Spatial test requirements

3.2.1 The Contractor shall characterize the spatial edge response based on measurements at the integrated instrument level, pre- and post-vibration testing, under simulated on-orbit operating conditions across the entire FOV in all bands. (CV-9).
Measurement conditions:

11 field angles (scale factors of field-of-view (FOV): -1, -.89, -.77, -.63, -.44, 0, .44, .63, .77, .89, 1.0)
0.05 IFOV increments from ± 3 IFOV from center of detector in both along-track and across-track directions
0.5 IFOV increments from 3 to 10 IFOV from center of detector in both along track and across-track directions
At the nominal and the high and low acceptance temperatures

Rationale: These measurements will be used to verify the OLI Edge Response requirements (Section 5.5. Edge response may be a function of location with the focal plane, hence the requirement to characterize across the entire FOV. The angular sampling provides equal enclosed area increments.

3.2.2 The Contractor shall demonstrate the edge slope response of the instrument VNIR bands remains within specification following observatory-level vibration testing at one previously measured (non-zero) field angle for each band.

3.2.2.a. The contractor may select the off-axis angle to be verified to provide the simplest test setup but the selected angle shall be documented in the calibration/validation plan (CV-1).

3.2.3. The Contractor shall characterize the stray light rejection and internal light scattering of the instrument based on measurements at the component level or above and analysis.

3.2.3.a The stray light model shall be developed using a Government-approved non-sequential ray trace method, e.g. ASAP, APART, GUERAP, or Trace Pro.

3.2.3.b The stray light model shall encompass the entire optical system, including baffles and the focal plane, detectors and mounting devices and all portions of the satellite bus and other payloads that may reflect light into the sensor.

Rationale: These measurements and analysis will be used to verify section 5.5.4 of the OLIRD and section __ of the IRD.

3.2.4 The Contractor shall include a stray light analysis of the solar diffuser panel(s) in the deployed position.

3.2.4.a This analysis shall include glints and shadowing on the diffuser by other observatory structures as well as the instrument itself.

3.2.4.b As part of this analysis, the Contractor shall demonstrate that diffuser measurements on orbit are not contaminated by reflected light from the Earth and the atmosphere.

3.2.4.c The contractor shall validate, by measurements at the integrated instrument level in two separate bands, the diffuser stray light model's (excluding observatory effects) prediction of the reflectance enhancement due to the diffuser instrument proximity.

Rationale: This characterization will allow the solar diffuser to be used as an absolute calibration source: the observatory, the sensor itself and the Earth may all contribute stray light to the solar diffuser.

3.2.5 The Contractor shall verify the ghosting requirements (sec 5.5.5 of the OLIRD) are met by using the stray light model in 3.2.3.

3.2.6 The Contractor shall verify the ghosting requirements (sec 5.5.5 of the OLIRD) are met by test at the integrated instrument level using a broad-band far-field illuminated object.

3.2.6.a The test object shall be scanned across the full FOV of the telescope.

3.2.6.b. The test object shall be at least 0.1 of the FPA across-Track FOV.

3.2.7 The Contractor shall measure the optical power and distortion of the thermal vacuum chamber optical window under expected thermal vacuum operating conditions.

Rationale: Spatial measurements performed through the chamber window will be affected by the window's optical properties.

3.3 Radiometric Test Requirements

3.3.1 The Contractor shall radiometrically calibrate all detectors at the integrated instrument level per the parameters in Table 3.3-1. (CV-9).

3.3.2 The Contractor shall characterize the radiometric response of all detectors across the expected instrument operating temperature range per the parameters in Table 3.3-1 (CV-9).

3.3.3 The Contractor shall collect calibration data sets and characterization data to demonstrate that the calibrated data will meet the absolute radiometric accuracy, pixel-to-pixel uniformity and radiometric stability requirements on orbit per the parameters in Table 3.3-1 (CV-9).

3.3.4 The Contractor shall determine the mathematical equation(s) to convert the instrument output in DN to input radiance per the parameters in Table 3.3-1.

Rationale: These tests (3.3.1-3.3.4) provide the basic radiance calibration of the instrument. The characterization of the mathematical form of the radiance calibration (e.g., linear) may be more accurately performed before integration of the focal plane into the instrument, whereas the final pre-launch calibration (3.3.1) is performed on the integrated instrument. Characterization of the temperature sensitivity of this calibration (3.3.2) is performed on a subset of the radiance levels used for the primary calibration. Verification that the instrument, the radiance calibration and the radiance calibration algorithm perform to requirements for accuracy, stability and pixel-to-pixel uniformity (in part) (sections 5.6.1, 5.6.2.3, 5.6.5) occur in 3.3.3.

3.3.5 The Contractor shall characterize the spectral bidirectional reflectance of the solar diffuser panel across the range of solar incidence angles and focal plane view angles to be used on orbit.
Measurement Details:

- 10 nm increment from 0.4 to 0.9 μm;
- 25 nm increment from 1.5 to 2.4 μm;
- 5 degree increment of solar zenith angle;
- 5 degree increment of view zenith angle;
- 5 degree increment of relative azimuth angle;
- Measurements performed to 5 degrees beyond expected angles of usage.

3.3.5.a The Contractor shall characterize the reproducibility of the diffuser deployment angle at the integrated instrument level.

Rationale: The solar diffuser provides the reflectance-based calibration of the instrument (section 5.6.1 of OLIRD); the characterization of the reflectance and deployment angles of the diffuser are required to use the solar diffuser as a reflectance calibration source, as well as a radiance calibration source assuming a knowledge of the solar spectral irradiance.

3.3.6 The Contractor shall characterize the stability of the internal calibration lamp system including the warm-up behavior until stabilization to within 0.1% of final output per the parameters in Table 3.3-1 (CV-9).

Rationale: The internal light sources provide the only technique for monitoring the short-term stability of the radiometric calibration, i.e., minutes to days.

3.3.7 The Contractor shall provide an integrated instrument-level observation of at least one on-board calibration device that is expected to be radiometrically stable through launch (CV-9).

3.3.7.a This observation shall be repeatable on orbit to assess the transfer of the pre-launch radiometric calibration to on-orbit calibration (i.e., Transfer to Orbit Measurement).

Rationale: A recurring problem with satellite sensors is a loss of certainty in the absolute calibration of the instrument during the launch process. Changes in conditions between ground and on-orbit, e.g. gravity, make certain devices perform differently. The contractor is required to provide a transfer to orbit calibration source (5.9.2.f of the OLIRD) that is free of known differences in performance between these environments. This device needs to be exercised during pre-launch testing and once on-orbit to assess the instruments stability through this period.

3.3.8 The Contractor shall characterize the Signal to Noise Ratio (section 5.6.2.1 of OLIRD) of all detectors per the parameters in Table 3.3-1. (CV-9).

3.3.9 The Contractor shall characterize the predictability of all imaging detector biases from the dark reference detectors for each SCA per the parameters in Table 3.3-1 (CV-9).

3.3.10 The Contractor shall characterize the bias stability and noise levels of all imaging and dark reference detectors per the parameters in Table 3.3-1 (CV-9).

Rationale: The bias stability of the imaging detectors and the correlation of the imaging detectors variation with the dark reference detectors are fundamental to the performance of the bias determination algorithm and thus ability to determine the bias values applicable to an individual acquisition. The longest continuous WRS-2 path over land masses is about 30 minutes in length.

3.3.11 The Contractor shall characterize the detector bias and gain stability across expected on-orbit on-off cycling of the instrument per the parameters in Table 3.3-1 (CV-9).

Rationale: Instruments when power cycled may restart in different bias and/or gain states.

3.3.12 The Contractor shall characterize the baseline 1/f noise parameters for all imaging and dark reference detectors per the parameters in Table 3.3-1 (CV-9).

3.3.13 The Contractor shall characterize the coherent noise of the instrument (section 5.6.2.4 of OLIRD) per the parameters in Table 3.3-1 (CV-9).

3.3.14 The Contractor shall characterize the dark level coherent noise of the instrument (section 5.6.2.4 of OLIRD) per the parameters in Table 3.3-1 (CV-9).

3.3.15 The Contractor shall characterize the linear polarization sensitivity of the instrument (section 5.6.4 of OLIRD) by component level measurements and analysis.

3.3.15.a The Contractor shall measure the linear polarization sensitivity of a sampling of detectors from each band (center and edges of field of view) per the parameters in Table 3.3-1.

3.3.16 The Contractor shall verify the bright target recovery and pixel-to-pixel electrical crosstalk requirements of the instrument (section 5.6.6 of OLIRD) per the parameters in Table 3.3-1.

3.3.17 The Contractor shall provide and maintain a detector operability status list which include dead, inoperable, and out-of-spec detectors for each band.

Table 3.3-1 Radiometric Test Minimum Acceptable Requirements

Test	Assembly Level	Measurement Ambient Atmospheric Conditions	Measurement Temperature Conditions	Radiance Levels	Calibration Source Location	Comments
3.3.1, 3.3.6, 3.3.8, 3.3.13	Integrated Instrument	Thermal Vacuum (nominal temperature)	Nominal operational focal plane temperature	Dark and 10 levels between 0.3 Ltypical and LMAX (dark and only 5 levels required for 3.3.13)	Ambient viewed through chamber window	Internal Lamps to be operated and warm-up behavior characterized during these tests
3.3.2, 3.3.6, 3.3.8, 3.3.13	Integrated Instrument	Thermal Vacuum	Alternate focal plane temperature set points	Dark and 5 levels between 0.3 Ltypical and LMAX	Ambient viewed through chamber window	Internal Lamps to be operated and warm-up behavior characterized during these tests
3.3.2, 3.3.6, 3.3.8, 3.3.13	Integrated Instrument	Thermal Vacuum (high and low temperature plateaus)	Nominal operational focal plane temperature	Dark and 5 levels between 0.3 Ltypical and LMAX	Ambient viewed through chamber window	Internal Lamps to be operated and warm-up behavior characterized during these tests
3.3.3, 3.3.6, 3.3.8, 3.3.11	Integrated Instrument	Thermal Vacuum	Nominal operational focal plane temperature	Simulated orbits with external calibration source, repeated to captured 16 day requirements	Ambient viewed through chamber window	Internal Lamps to be operated and warm-up behavior characterized during these tests; FPA reset as per on-orbit ops

3.3.4, 3.3.16	Focal plane level or above	No requirement	Nominal operational focal plane temperature	20 levels between dark and LMAX for 3.3.4		
3.3.9, 3.3.10	Integrated Instrument	Thermal Vacuum	At each operational focal plane temperature set point	Dark Level, measurements over 40 minutes (may be sampled) in simulated orbits, three repeats at nominal temperature set point	N/A	
3.3.12	Integrated Instrument	Thermal Vacuum	At each operational focal plane temperature set point	Dark Level, continuous measurements over 40 minutes	N/A	No FPA on-off cycling or resets during the measurements
3.3.14	Observatory	Thermal Vacuum (high and low temperature plateaus)	At each operational focal plane temperature set point	Dark Level	N/A	
3.3.15.a	Integrated Instrument	No requirement	At operational focal plane temperature set point	No requirement	N/A	

3.4 Geometric Test Requirements

3.4.1 The Contractor shall measure each detector's LOS relative to the instrument coordinate system, to an accuracy ≤ 6 μrad (3-sigma), at the integrated instrument level.

Rationale: Band-to-band and image-to-image registration error budgets are driven by platform stability and line-of-sight knowledge and stability. The current error budgets assume 6 μrad (3-sigma) LOS knowledge and stability. On-orbit results from ALI showed focal plane calibration consistency of 3.9 μrad (3-sigma) for SCA-level offset, rotation and scale parameters.

3.4.2 The Contractor shall demonstrate the relative thermal stability of the detector lines of sight by measuring the relative locations of a selected set of detectors at the nominal, maximum and minimum expected operating temperatures, to an accuracy ≤ 3 μrad (3-sigma), at integrated instrument or observatory level, post-vibration.

3.4.2.a The selected set of detectors shall include, at a minimum, the first, middle, and last detector in each row, if multiple rows of detectors are provided, e.g., due to even/odd detector stagger or the inclusion of redundant detectors, from each band on each SCA.

Rationale: Line-of-sight stability (over the range of expected operating temperatures) of 6 μrad (3-sigma) or better is required by the current band registration and image registration error budgets. The measurements intended to demonstrate stability to this level must be more accurate by a factor of 2 or better.

3.4.3 The Contractor shall characterize the detector-sampling timing pattern, to an accuracy of 150 microseconds (3-sigma) or better, via measurement of any detector-specific electronic delays, sample phasing (e.g., even/odd detector timing offsets), and frame rate (i.e., time between samples) for each detector.

Rationale: Detector to detector timing/latency variations must not significantly degrade the line-of-sight knowledge of 6 μrad (3-sigma). Timing knowledge to 50 microseconds corresponds to an additional LOS uncertainty of approximately 1.5 μrad. This is slightly less that the overall absolute timing knowledge accuracy requirement of 200 microseconds (3-sigma) cited in SSRD sections 11.1 and 12.1.

3.4.4 The Contractor shall measure the alignment of the instrument optical axes relative to the OLI alignment reference/ alignment cube.

Rationale: The prelaunch alignment of the instrument to the ACS reference frame is an initial measurement used to get the on-orbit calibration procedure started. The actual instrument alignment is expected to shift due to launch and zero-G release. This measurement is the instrument portion of the overall OLI to observatory ACS alignment measurement. The geodetic accuracy error budgets are based on on-orbit alignment calibration accuracy so the accuracy of the prelaunch measurements is not critical.

3.4.5 The Contractor shall demonstrate the ability to reconstruct and register images in all spectral bands from data collected under conditions that simulate the on-orbit target motion (CV-9).
Note: This demonstration may be performed in segments over the full FOV of the instrument.

Rationale: This test is intended to verify the integrity of the instrument to recorder data path.

3.4.6 Following observatory-level vibration testing, the Contractor shall demonstrate that the data from the VNIR detectors are mapped to the correct locations in the observatory downlink data stream.

Note: This test may be performed using an internal source.

Rationale: This observatory level test is intended to demonstrate that the instrument and spacecraft data handling systems were successfully integrated and that no data connections were damaged during vibration testing. An internal source that provides input that varies across the focal plane should be sufficient for verifying the integrity of the data path.

4 On-Orbit Commissioning Phase Test Requirements

4.1 Spatial Test Requirements

4.1.1 The Contractor shall examine the stray light and ghosting of the instrument using the moon at least twice, using data acquired at least 16 days apart.

Rationale: Although a true characterization of the stray light response and ghosting is not possible using the moon, the data can be examined for effects that are not predicted by the stray light model. In other instruments, e.g. ALI and ASTER lunar views have revealed stray light and ghosting issues.

4.2 Radiometric Test Requirements

4.2.1 The Contractor shall characterize on-board lamp based calibrator on-orbit performance and stability including warm-up behavior and within and between orbit stability relative to the instrument.

4.2.2 The Contractor shall characterize the variation in the BRF of the solar diffuser across the range of azimuth and zenith angles to be used for on-orbit calibration.

4.2.3 The contractor shall characterize the reproducibility of the solar calibration technique with a minimum of 5 measurements, with each measurement acquired a minimum of 1 day apart.

4.2.4 The contractor shall complete the on-orbit portion of the Transfer to Orbit Measurement (See SCTR 3.3.7).

4.2.5 The Contractor shall characterize the stability of the instrument by reference to the internal lamps by a minimum of daily measurements.

4.2.6 The Contractor shall update the absolute calibration coefficients and uncertainties as required to meet performance specifications.

4.2.7 The Contractor shall characterize any variations in detector responsivity over a minimum of 2 instrument outgassing cycles, if outgassing is required.

4.2.8 The Contractor shall characterize the relative detector response for detectors within a band and update the calibration parameters to correct pixel-to-pixel non-uniformity as necessary.

4.2.9 The Contractor shall characterize both the coherent and total noise of the instrument at dark and at multiple (at least 2) illuminated levels between dark and Lhigh at least twice with data acquired at least 16 days apart.

4.2.10 The Contractor shall characterize the bias stability for all imaging and dark reference detectors over a 40-minute period at least twice, with data acquired a minimum of 16 days apart.

4.2.11 The Contractor shall characterize the 1/f noise parameters for all imaging and dark reference detectors over a 40-minute period at least twice, with data acquired a minimum of 16 days apart.

4.2.12 The Contractor shall characterize the predictability of the imaging detectors biases from the dark reference detectors over a 40-minute period at least twice, with data acquired a minimum of 16 days apart.

4.2.13 The Contractor shall characterize the performance of the bias determination algorithm using on-orbit data for acquisition intervals of up to 40 minutes.

4.2.14 The Contractor shall support imaging the full lunar disk at a phase angle of 5° to 9° or -9° to -5°.

4.2.14.a At least 2 SCA's shall image the moon at least twice during commissioning at the same phase angle, one lunar cycle apart.

4.2.14.b All SCA's shall image the moon at least once within this same 4° increment of phase angles.

4.2.15 If Landsat-7 is still operational, the Contractor shall support collection of data of common ground targets within 20 minutes of the Landsat-7 ETM+ acquisitions.

4.2.16 The Contractor shall update the detector operability status list with newly identified dead, inoperable, and out-of-spec detectors for each band.

Rationale: To the extent possible, the pre-launch radiometric tests need to be repeated on orbit to assess whether anything has changed since pre-launch testing and to characterize the system under its actual operating conditions. Noise levels, particularly coherent noise, may change with the change in grounding of the spacecraft. The radiometric response, both absolute and relative, may change during launch. Calibration techniques not readily available prior to launch, e.g., solar and lunar calibration, need to be conducted and their repeatability assessed.

4.3 Geometric Test Requirements

4.3.1 The Contractor shall characterize the instrument to Attitude Determination System Reference alignment.

Rationale: The instrument alignment is expected to change due to launch shift and zero-G release, so an on-orbit update is required to achieve the required on-orbit geodetic accuracy performance. The accuracy is here left as a component of the overall geodetic error budget to be determined by the contractor. Internal error budgets call for an alignment calibration accuracy of 45 microradians (3-sigma).

4.3.2 The Contractor shall characterize the detector arrays lines of sight for bands 1-8 relative to the panchromatic band using ground targets at least twice, using data acquired at least 16 days apart.

Rationale: The prelaunch line-of-sight calibration could change on-orbit due to the reaction of the optical system to launch and/or zero-G release. Any such changes would be expected to be slowly varying (not detector-by-detector) and subject to calibration using SCA-level on-orbit adjustments (as was done for the ALI). Once on-orbit, these LOS measurements are necessarily relative, so the calibration operation measures the offsets of bands 1-8 relative to the panchromatic band. The accuracy is here left as a component of the overall band registration error budget to be determined by the contractor. Internal error budgets call for a band alignment calibration accuracy of 6 microradians (3-sigma).

4.3.3 The Contractor shall characterize the alignment of band 9 (cirrus) relative to the other reflective bands using the lunar scan data described in 4.2.

Rationale: The band alignment procedure used for bands 1-8 (see previous requirement) are unlikely to be effective for the cirrus band which will not provide clear images of ground targets. Instead, this procedure must be carried out using the lunar scan data. The accuracy is here left as a component of the overall band registration error budget to be determined by the contractor. Internal error budgets call for a band alignment calibration accuracy of 6 microradians (3-sigma).

4.3.4 The Contractor shall characterize the relative locations of the individual SCA's on the focal plane at least twice, using data acquired at least 16 days apart.

Rationale: The prelaunch line-of-sight calibration could change on-orbit due to the reaction of the optical system to launch and/or zero-G release. Any such changes would be expected to be slowly varying (not detector-by-detector) and subject to calibration using SCA-level on-orbit adjustments (as was done for the ALI). Once on-orbit, these LOS measurements are necessarily relative, so the calibration operation measures the offsets of each SCA relative to the mean of the SCA's. The accuracy is here left as a component of the overall image-to-image registration error budget to be determined by the contractor. Internal error budgets call for an SCA alignment calibration accuracy of 6 microradians (3-sigma).